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THE EUROPEAN RED MITE IN OHIO

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OHIO AGRICULTURAL EXPERIMENT STATION - - WOOSTER, OHIO

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INTRODUCTION

In recent years, one of the most serious pests of apple and other fruits in Ohio has been the European red mite, *Panonychus ulmi* (Koch). The following account of this species is written principally for horticulturists. It deals with the life history, with certain phases of the biology and ecology of the pest, and with certain fundamental problems in the field of control. Since recommended control measures are frequently changed, this bulletin will not deal directly with this subject. The latest information on this point may be obtained from the official spray schedules of the current year.

SYNONYMY

In the literature dealing with the European red mite, several different scientific names have been used. In the United States it was first known as *Tetranychus mytilaspidis* Riley, but this was soon changed to *Paratetranychus pilosus* (Can. and Fanz.). This name was used for a period of approximately forty years (1912-1952). From 1952 to 1956 it was called *Metatetranychus ulmi* (Koch) and since the latter date, *Panonychus ulmi* (Koch).

It is not the purpose of this publication to list in detail the reasons for the name changes, but rather to present them as facts necessary for anyone to know who must use the literature.

A complete list of synonyms of *Panonychus ulmi* (Koch) is found in Pritchard and Baker (28), although in that volume the name used is *Metatetranychus*. The change to *Panonychus* was made by Ehara (12).

GEOGRAPHICAL DISTRIBUTION

The European red mite is found in practically all of the principal apple growing areas of the world. It is primarily found in the cool areas of the temperate zones, though some extensions into warmers areas have occurred in recent years. There are authentic reports of its presence from all continental European countries where apples are grown and from the British Isles. It is also reported from North Africa (Algeria). Orchards in the United States and Canada suffer severely from attacks of the pest. It is also present in Japan, Asiatic Russia, and Turkey.

In the southern hemisphere, it is reported from South Africa, South America (Chile), New Zealand and Tasmania.

HISTORY

(In the United States and Ohio)

In the United States, the European red mite was first found by Ewing (13) in Oregon in November 1911. It was first observed in most of the eastern states and in Canada during the period from 1912-1920.

The exact date of its introduction into Ohio is not known. However, definite reports of injury to peaches in Ottawa County in 1917 and to apples in Mahoning County in 1919 were undoubtedly due to this species. By 1921, reports of injury were received from several orchards in northern Ohio, and a control project was undertaken by Dr. J. S. Houser, entomologist at the Ohio Agricultural Experiment Station. These experiments led to the use of petroleum oils, applied in the late dormant period, as controls. This recommendation, with certain modifications, is still effective.

At first it was thought that the single application of oil in the spring would control mites for the season. However, by 1925 it was evident that midsummer control sprays would also be needed and the writer was assigned to this problem. Several seasons were spent investigating the possible use of oils during the summer months. These tests were abandoned in 1928 when it was clearly shown that oils used in summer caused too much injury to foilage and spotting of the fruit; also, there were difficulties in combining them with sulfur which was the principal fungicide of that day. It should be recognized that the oils of this period were less refined and more likely to produce injury than those of today.

Other materials tested prior to World War II, were different forms of sulfur, rotenone, azobenzene, etc. However, the material found to be most effective was a dinitro compound called DN-111, produced by the Dow Chemical Company. This was first recommended in 1942 and continued in use until 1948 when it was replaced by less phytotoxic materials.

Prior to the introduction of DDT in 1946, serious out-breaks of the European red mite, while common, were of a sporadic nature. That is, an orchard would be damaged by mites one season or even for two or more successive years. This period of attack might be followed by a season or two, or more, in which the mite population would be quite low and the orchard would escape damage. The area in Ohio where mite attacks were most severe was limited to northern and northeastern Ohio.

Following the introduction and wide use of DDT, the situation in regard to the area of severe infestation and the amount of damage. changed remarkably. Almost at once mite injury became severe throughout southern Ohio and the pattern of annual attacks by mites became common.

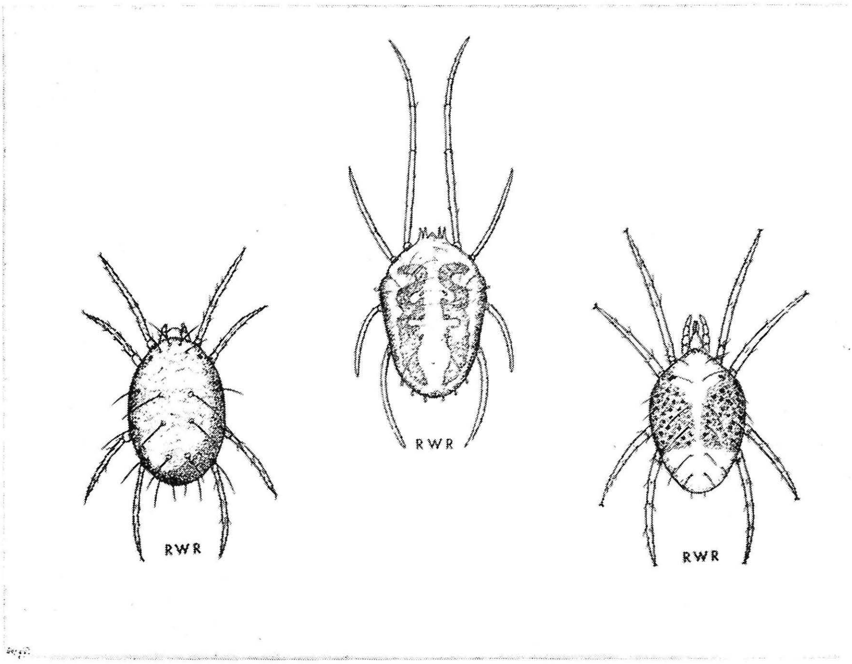
To understand the reasons for these changes, one must recognize the fact that heavy populations of mites do not develop in unsprayed or uncared-for orchards. This is due to the effective work of their natural enemies which flourish in the absence of spray chemicals. Prior to 1946, the chemicals in use were less toxic than DDT to the beneficial species. For example, sulfur is toxic to some species but not to others, while DDT is toxic in some degree to practically all. Therefore, the wide use of DDT, which freed the European red mite and other mite species from the attacks of their natural enemies was the cause of the increased seriousness of the mite problem.

Thus in 1947-1948, the control of mites, particularly the European red mite, became the number one problem in the field of insect and mite control for the Ohio apple grower. Since the same condition arose in neighboring states and in other apple growing areas of the United States and Canada, entomologists of the agricultural experiment stations and of the leading manufacturers of pesticidal chemicals organized research to produce more effective miticidal materials. This effort resulted in the production of Dimite, HETP, and TEPP as early as 1947-1948. Numerous other miticidal compounds followed and have been used since 1949. These will be further discussed under the heading of Miticides Used in Ohio.

DESCRIPTIONS

The Egg: The egg of the European red mite is globular and somewhat flattened. When magnified, it shows many grooves running toward the center from which a slender, tapering stalk arises. This stalk is usually no longer than 0.1 millimeter (mm) and may be curved or twisted. When first deposited, the summer egg is bright red but later becomes dark orange. The over-wintering egg is a deeper red and slightly larger than the summer form. According to Newcomer and Yothers (25), summer eggs will average 0.132 mm in diameter while the winter forms average 0.148 mm.

The Larva or First Instar: This name is applied to the young mite during the period from hatching to the first molt. Af first it is light orange in color but soon becomes a deep red with perhaps a trace of brown. This stage has only six legs. The larvae are usually no more than 0.2 mm in length.



Adult females of (left) the European red mite, (center) the clover mite, (right) the two-spotted spider mite.

Second Instar: This stage is frequently called the protonymph and is distinguished by having 8 legs as do all following stages. After feeding it may appear dark green due to ingested food although the normal color is red. This stage is only slightly larger than the larvae.

Third Instar: This stage also called the deutonymph, is very similar to the second instar and somewhat larger. The sexes can be differentiated; the female being more rotund and larger than the slender male

The Adult: The female will average from 0.30 to 0.38 mm in length, the body is robust, brick red in color and carries four rows of spines or bristles borne on raised white tubercles. The males are lighter in color and may be greenish following feeding. They carry the four rows of bristles but the body is slender and smaller than the female.

HOST PLANTS

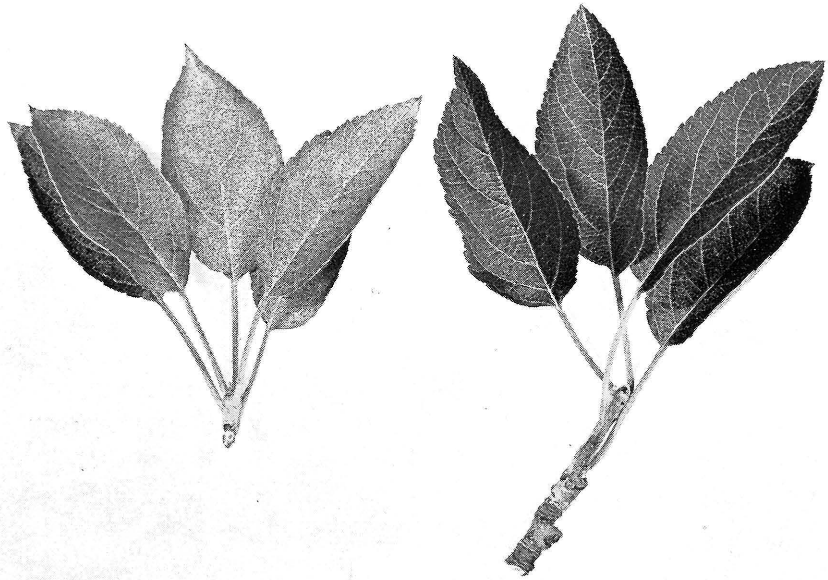
The two hosts that surffer most severely from attacks by the European red mite in Ohio are apples and European plums. Pears are also attacked, but as they are a minor crop in Ohio, little attention has been paid to mites on this host. The peach is also a primary host and in certain seasons may suffer severely though it is not as subject

European red mites on the underside of apple leaf.

to severe annual attacks as is the apple. In Ohio, both sweet and sour cherries are largely immune from attack. Other Ohio hosts are crab apple, different hawthornes, elm, locust, and possibly wild cherry.

INJURY

As already stated, apples, European plums, peaches and pears are the hosts that suffer most seriously from mite attack. No variety of these fruits escapes but some are more subject to injury than others. Among apples in Ohio, the Red Delicious is by far the favorite host, followed by Stayman Winesap, Golden Delicious and Baldwin (Figure 5). Varieties less subject to injury are McIntosh, Rome Beauty, Jonathan and Wealthy, although in certain seasons none of these escape.



Injury to foliage by the European red mite. Leaves at the left show injury while those on the right are not affected.

No study has been made in Ohio of the susceptibility of different varieties of pears, plums, or peaches.

The leaves of the tree are the tissues that are directly injured by the feeding of the mites. Feeding takes place on the undersides of the leaves, where the majority of mites, especially the immature forms, are to be found. Adult mites may feed on both surfaces and are frequently noted on the upper surface when populations are heavy and the "food" condition of the leaf is unfavorable. Feeding consists of the piercing of the cell walls by the bristle-like mouth parts and of the ingestion of the cell contents, including the chlorophyll. Resultant injury is manifest in varying degrees by off-color foilage. Feeding by a few mites, say four to six, will not produce visible injury on a large leaf, nor will the feeding of a much greater number of young mites for only a short period of time. However, as the mites increase in number, visible injury appears. At first this may be little more than a dulling of the normal green color of the leaves. This is followed, unless the mites are destroyed, by a definite bronzing of the leaves. The difference between such leaves and normal foilage is so great that even an untrained observer will notice it.

In very severe cases, bronzed leaves will continue in decline, turning brown and falling from the tree. This is frequently noted in dry seasons. When leaves have been seriously injured, they are in very poor condition to withstand the shock of a spray application. For example, from 1935 to 1945, when lead arsenate was almost the only insecticide for summer use, orchards severely injured by mite feeding were frequently defoliated following the use of this spray material.

The earlier in the season that mite injury occurs, the greater the damage to the trees and the fruit. Trees that are injured in June will not form the normal number of flower buds for next year's crop and many of those formed will be weak. In fact, a very severe attack may stop all flower bud formation and may leave the tree barren for the coming season. When injury occurs in July and early August, fruit which the tree is carrying will be smaller and of poorer quality. All these effects are due to the fact that the injured leaves are not able to supply elaborated food materials to the fruit in proper quantity and quality. In late August and in September, mature leaves will support many mites without visible injury. Such a population, however, will deposit thousands of overwintering eggs on twigs, branches and in the calyx areas of the fruit. This will result in heavy populations the coming spring.

Leaves that have experienced up to medium injury may recover their normal functions and appearance if the mite population is destroyed either by spraying with an effective miticide or by other means, *i.e.* biological control. However, leaves that have received maximum injury will make little if any, recovery.

LIFE HISTORY

The Overwintering Egg: The European red mite passes the winter only in the egg stage. These overwintering eggs are placed usually in groups, near or in roughened areas of the bark such as exist around the base of buds, spurs, wounds, and points that mark the beginning of new growth. At times, these eggs may be so numerous that the twigs and smaller branches may appear to be covered with spots of dried blood. Eggs may also be deposited in numbers in the calyx and stem ends of the fruit and may be noted occasionally on scab spots. They are seldom placed on leaves.

Overwintering egg deposition may start under certain conditions as early as mid-August and extend into late November. The time of heaviest oviposition usually occurs in October.

Since the overwintering eggs are in positions where they can be readily reached by spray and since the season is that in which foliage is no obstacle to thorough coverage, the eggs are especially vulnerable to attack. Therefore, entomologists are greatly interested in the overwintering eggs which have been the subject of much study. These eggs are on the tree for a period of five to eight months, during which time they are exposed to all types of autumn, winter, and spring weather. The extremes of winter temperature have little effect on the hatching of the egg. Hatches of the overwintering eggs at Wooster, Ohio, have varied from 32 percent in 1947 to 90 percent in 1950. However, in studying the data on annual hatching from 1939-1963 (see Table 1), there is little, if any, correlation between low winter temperature and low hatching rates. The rate of hatching of eggs from different orchards or even from different sections or different varieties in the same orchard may vary tremendously in the same season. For example, in 1955 in Columbiana and Mahoning counties the highest percent of hatch of eggs from Red Delicious trees was 98 and the lowest 41. From the variety Rome Beauty, the highest was 99 percent and the lowest 44 percent. In 1960, the highest percent hatch was 82 and the lowest 52. In these cases, eggs were collected from thirteen orchards each year and the comparisons are between these different lots of eggs. In 1961, with fewer orchards involved, the highest rate of hatch was 65 percent and the lowest 35 percent. All these orchards were in the same general area and subject to very similar weather conditions.

There are, of course, reasons for such wide fluctuations in hatching. For example, in November 1950, mite eggs were collected from four different orchards in northern Ohio. These were kept out-of-doors but under shelter, that is, they were protected from rain, snow, ice and possibly from some of the extremes of temperature that occur in the orchard. They were not exposed to sunlight. During March of 1951, similar lots of eggs were taken from the same trees in the same orchards and all were observed for hatching.

The results showed that the sheltered eggs hatched at a higher rate than those that were overwintering in the orchard. A few experiments were conducted to find possible reasons for these differences. It was thought that the freezing of ice around the eggs on the trees might affect them. However, when eggs were frozen in ice for 5 days, 60 percent still hatched which was almost equal to the check. When frozen in ice for 15 days, hatching was reduced to 41 percent. Conditions such as this would rarely exist in any winter in Ohio orchards.

Another experiment dealt with the submergence of eggs in water and other solutions. Eggs kept under water for 48 hours hatched at a normal rate and the same was true for eggs in a 1-1600 solution of

TABLE 1.—Hatching of Overwintering Eggs of the European Red Mite. Seasonal Data from 23 Different Years.

Year	Date of First Hatch	Date of Last Hatch	Length of Hatching Period	Date of Peak Hatch
			Days	
1939	May 5	May 15	10	May 9
1940	May 6	May 18	9	May 12
1941	Apr. 21	May 7	17	Apr. 28
1942	Apr. 18	May 4	16	Apr. 26
1943	Apr. 29	May 17	19	May 8
1944	May 1	May 12	12	May 4
1945	Mar. 31	Apr. 20	21	Apr. 10
1946	Apr. 1	May 1	31	Apr. 22
1947	May 1	May 23	23	May 11
1948	Apr. 5	Apr. 23	18	Apr. 16
1949		Incomplete Data		
1950	May 6	May 16	10	May 10
1951	Apr. 29	May 8	9	May 2
1952	Apr. 21	May 9	18	May 1
1953	Apr. 23	May 11	18	May 3
1954	Apr. 18	May 6	18	Apr. 25
1955	Apr. 13	Apr. 29	16	Apr. 18
1956	May 1	May 23	23	May 11
1957		Incomplete Data		
1958	Apr. 20	May 11	21	Apr. 24
1959	Apr. 18	May 8	20	Apr. 27
1960	Apr. 23	May 7	14	Apr. 26
1961	Apr. 23	May 7	14	Apr. 25
1962	Apr. 28	May 12	14	May 2
1963	Apr. 1	June 2	63*	Apr. 29

*The longest hatching period on record occurred in 1963. This was due to almost continuous cold weather during April and May which followed a few warm days in late March.

nicotine sulfate. However, eggs in a one percent oil emulsion were all killed after four hours of submergence

Some idea of the effect of different degrees of humidity was obtained from an experiment where eggs were kept at different humidity levels. This showed that eggs hatched best at humidities from 50 to 80 percent. The hatch was greatly reduced as humidity approached zero or 100 percent. Apparently, the overwintering egg is well qualified to cope with practically all types of weather.

Hatching: Following oviposition in autumn and during the winter months, the egg is largely quiescent. Embryonic development occurs usually after temperatures start their upward trend in the spring months. The Japanese investigators Tsugawa, *et al.* (31) state that development does not begin until temperatures will average at least 7° C, or approximately 45° F. As average daily temperatures increase above this point, activity within the egg is also accelerated and the point at which hatching takes place is reached when a total of 195° C day degrees have accumulated. In day-degrees Fahrenheit, this is 383 above the developmental zero, (45° F).

In hatching, a break or crack develops around the egg at the point of its greatest diameter and it is through this that the young larva emerges. The two halves of the egg-shell do not entirely separate and remain attached to the bark. When the egg shells are abundant they give the twig surface a greyish-white appearance, somewhat like the growth of a mold or mildew.

The first hatching usually occurs when the earliest blossom buds of Red Delicious show pink (Figure 1). The date of this occurrence of course, varies widely from year to year, depending on prevailing temperature, sunshine, rainfall, and other conditions. At Wooster, the earliest date of hatching of the overwintering eggs on record was March 31, 1945, and the latest on May 6, in both 1940 and 1950. The date of last hatching has occurred as early as April 20, 1945 and as late as June 2, which took place in 1963. Peaks of hatching occurred at the earliest on April 10, 1945, and as late as May 11 both in 1947 and 1956. The period of egg hatching has been as short as 9 days (1939 and 1951) and as long as 63 days in 1963—(Table I).

Following the hatching of the last overwintering eggs and before the first hatching of the eggs of the first generation mites, there is a short period (four to ten days) in which no eggs are present on the trees. This period is of importance in reference to control and will be discussed later in more detail.

First Generation Mites: First instar mites, or larvae, hatching from the overwintering eggs seek the young leaves on which to feed. At this season, these leaves are small and frequently not fully unfolded. To find such favorable food, the young must crawl varying distances; in some cases even a foot or more. When a leaf is found, the mite seeks the under surface or crawls down into the cluster of unfolded leaves. The feeding period is rather short and will vary greatly according to weather conditions. Usually it will average three days. This is followed by a resting stage in which the mite is prepared for molting and which will last slightly less than the time needed for feeding. The overall time required for the first instar will average from four to six days. Neither the second instar (protonymph) nor the third instar (deutonymph) requires as much time for feeding or quiescence as does the larva. The total time necessary for the development of all the immature stages will vary tremendously according to the individual and to weather conditions. Generally it will average from 10 to 12 days.

Molting or the casting of the old outer covering or skin occurs at the end of each quiescent period. This is accomplished when a break occurs across the back of the thorax. The abdomen is first

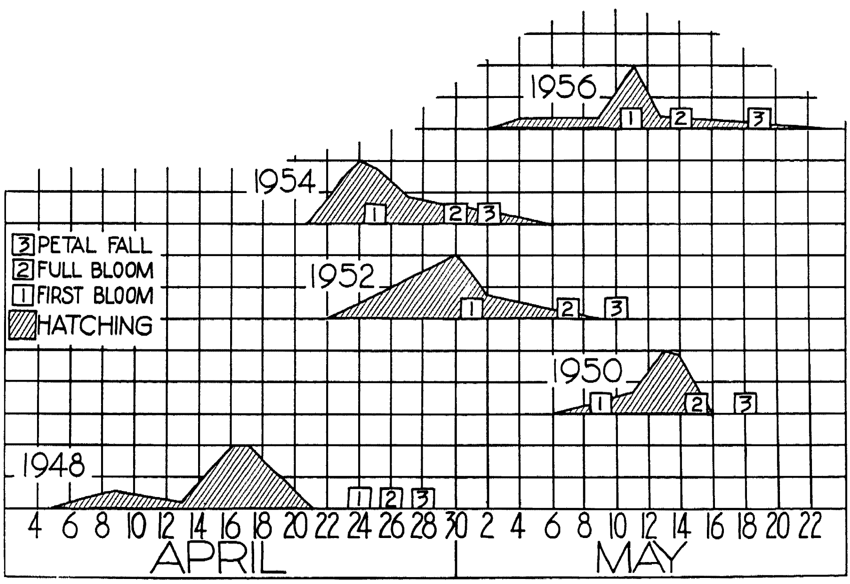


Fig. 1.—Hatching of overwintering eggs of the European red mite in different seasons, as influenced by different weather conditions.

freed, following which the mite backs out of the forward portion of the old skin. If males are present, mating occurs immediately after the last molt of the female. Eggs from mated females will produce both male and female offspring but the eggs from an unmated female will produce only males.

Following the last molt, two to three days usually pass before egg-laying starts. The period of egg-laying or oviposition also varies greatly in length but for all broods will average from 10 to 15 days. When this period is complete, the mite will live a few additional days. Thus, from the hatching of the egg to the death of the adult female, a period averaging about 24 days will elapse. However, it must be realized that periods much shorter or longer than this do occur. Eggs laid by females of the first brood may incubate and hatch in as short a period of time as six days or as long as 15 days, eight to ten days being the average.

In terms of what occurs in the orchard, this means that if a female mite was hatched on May 1, she would probably start egg-laying on May 14. These eggs would hatch on May 24 and the cycle would start over again. Thus a total of 24 days would be required for the complete life of an individual mite.

However, all the overwintering eggs did not hatch on May 1. For example, (Table 1) in 1952 the peak of hatching occurred on May 1, but the first egg hatched on April 21 and the last on May 9 a hatching period of 18 days. All of these hatched mites will vary in the length of the developmental period (6 to 10 days), and the oviposition period (3 to 22 days). This means that hatching of the first generation of summer eggs could start before May 10 and extend into late June for a possible hatching period of 47 days.

Second and Succeeding Generations: Due to warmer weather, the time for the development of individual mites during the summer months is somewhat shorter than for those of the first brood. However. due to varibility, as discussed in the preceeding paragraph, the actual time for the completion of these broods as a whole will be longer and will result in overlapping broods as early as late June. This, of course, will continue and become more complex as the season progresses. Finally, in August, September and early October, it is entirely possible that mites from at least three broods will be present on the same tree or even on the same branch.

Based on the foregoing data, it appears entirely possible that eight broods will occur in Ohio in a single season, especially if temperatures are above normal, as for example, in 1962. However, observations extending over a period of 25 years show that five complete broods is the normal number plus mites that form partial sixth, seventh, and eighth broods.

The relatively short time necessary for the development of a complete brood plus the number of broods that occur each season indicates the great potential of the European red mite to produce infestations of damaging numbers; also, the fact that individual females will produce on an average from 20 to 30 eggs, places further emphasis on this point. By a simple process of arithmetic, it can be shown that a single pair of mites of the first brood can multiply to a number of over one-half million in the fifth brood. Therefore, if a tree starts the season with a population of 10,000 overwintering eggs, which is a reasonable figure, the possibilities of an early and destructive infestation are great unless natural or man-made controls intervene.

FACTORS INFLUENCING SEASONAL PATTERNS OF INFESTATIONS AND INJURY

Initial Populations: The number of mites hatching from the overwintering eggs constitute the initial population. The number of overwintering eggs has been influenced by factors of the previous season that have been favorable or unfavorable to the deposition of the eggs. Usually trees that have been severely attacked by mites in midsummer will carry only a few eggs as the population will have been depleted due to poor food and predators. This will have occurred prior to the season of heaviest egg deposition. Trees with foliage in good condition in late August and early September will usually carry far greater numbers of overwintering eggs. This is due to ample food and other favorable factors.

When other factors are equal, data taken from trees with low numbers of eggs as contrasted with high numbers of eggs, show that trees with high numbers always develop larger and more damaging populations of mites at earlier dates. Data also show that it is more difficult to combat and reduce these high populations. Thus it is that initial numbers must always be considered as a factor in seasonal trends.

Weather Conditions: These are very important, especially during the early part of the season. Following hatching, the young mites are very susceptible to low temperatures. Many instances have been observed in which threatening numbers of young mites (15 to 25 per leaf) were killed to a point where they were practically harmless. For example, in the spring of 1961, mites hatched in large numbers. However, toward the end and following the hatching period

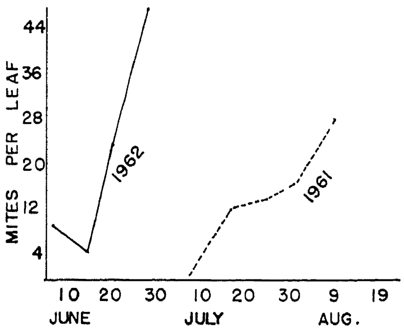


Fig. 2.—Effect on mite populations of different weather conditions.

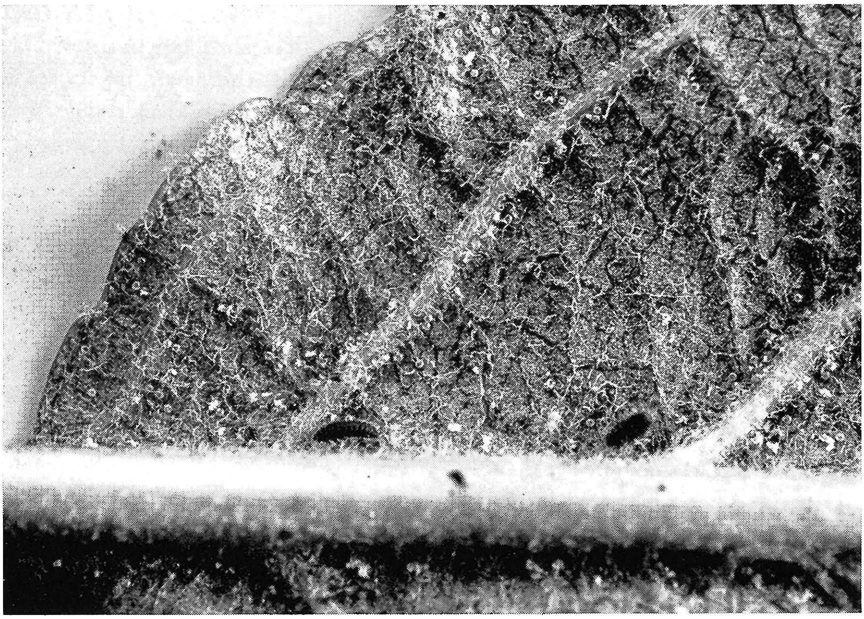
there were several nights with temperatures dropping as low as 27° F. Under these conditions mites suffered a heavy mortality and serious infestations did not develop until late July. On the other hand, in 1962 there was no period of low temperature during or following hatching and mites became serious from mid-to late-June (Figure 2).

While mites are active at somewhat lower temperatures than many insects, all their life processes are speeded up by temperatures within the general range of 70 to 90° F. Above this point activities are retarded. Although temperature is the most important of the weather factors, wind plays a part in dispersing mite populations and low humidity will reduce hatching of eggs. Varying degrees of light seem to influence the movements of mites within the tree.

Natural Enemies: The literature dealing with the European red mite contains many references to their natural enemies. These have been studied most intensively in England where Collyer (4,5,6) has listed 45 species of other mites and insects as attacking the eggs, immature forms, and adults of the species under discussion. Collyer also lists nine species of predaceous *Typhlodromus* mites, though some of these may not attack the European red mite.

In the United States and Canada, investigations of predators have been made by Garman (14,15), Newcomer and Yothers (25), Lord (19,20), MacPhee (21), Hintz (17), Snetsinger (30) and others; but the number of natural enemies of the European red mite listed is not nearly as large as that accumulated by Collyer (4,5,6). This is probably due to the fact that the species was brought to the United States without many of the natural enemies that attack it in Europe.

In Ohio, Hintz (17) has made field observations on a number of predators, particularly the ladybird beetle, *Stethorus punctum* (LeC.) but the general work with natural enemies has not been extensive. How-



Larvae of the ladybird beetle Stethorus punctum **(LeC.) feeding on motile forms of the European red mite on apple foliage.**

ever, predators from at least five major biological systematic groups, namely, (1) predaceous mites, (2) ladybird beetles, (3) predaceous thrips, (4) true bugs (mirids and anthocorids) and (5) true flies (dipterons) have been listed.

Among the predaceous mites in Ohio, members of the genus *Typhlodromus* are most conspicuous on apples. They are a very definite factor in the control of mites on unsprayed trees but not so effective in sprayed orchards. This has also been noted in Illinois by Snetsinger (30). In orchards where mite populations are high, particularly after the spray program of the season is ended.*Typhlodromus* mites will frequently develop in numbers and will be a definite aid in control. Unfortunately, this almost always occurs after severe damage has taken place.

The most efficient predator among the ladybird beetles is *Stethorus punctum* (LeC.). This is a very small, robust, black ladybird that is commonly found in connection with heavy mite infestations toward the end of the growing season. Both larvae and adults feed on the eggs and on motile mites, thus making the species doubly efficient. In two instances, in a period of over 30 years, seasonal control of mites by this ladybird has been observed. One orchard was first observed about mid-June when limited numbers of mites were found accompanied by a low active population of this ladybird beetle. Observations were continued at two week intervals and on all such occasions the two populations remained almost the same. In other words, there was no increase in the mite population and no injury to the trees. The evidence was definite that the controlling agent was *Stethorus punctum* (Figure 3).

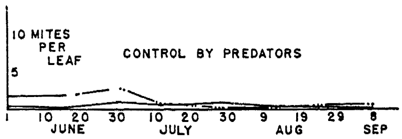


Fig. 3.—Mite populations in two orchards controlled by predators. Unfortunately, this type of control is extremely rare.

In the other orchard, conditions were similar but observations did not start until mid-July. In both cases lead arsenate was the insecticide and no miticide was used.

Other ladybird beetles, such as the two-spotted, *Adalia bipunctata* (L.), have been listed as preying on mites but this has not been observed in Ohio.

Immature forms of at least two species of thrips have been observed feeding on the European red mite. Unfortunately, the species involved were not identified. *Scolothrips sexmaxulatus* has been listed as a mite predator in several other states and it is probable that this is one of the species.

True bugs belonging to the anthocorid and mirid families have also been observed attacking red mites in Ohio. These are not as abundant as reported in England, Canada and some other areas of the United States, and their predation in this state seems to be of minor importance.

Syrphid fly larvae (order Diptera) have been reported as mite predators. They have been observed in mite colonies in Ohio but have not been seen to attack the mites.

The Spray Program: It has already been stated that the unsprayed apple orchard will have little difficulty with phytophagous, or plant-feeding mites and that this condition is due to the presence and activities of their natural enemies. Unfortunately, the natural enemies are largely destroyed by the sprays that are necessary to protect the fruit and the foliage from insect pests and diseases. Some spray programs, depending on the chemicals employed, are more destructive to natural enemies than others. Among the most harmful materials in use in 1962 were DDT, Sevin, and various organo-phosphates, including Guthion. On the other hand, the program may include miticide materials that are so effective against the European red mite and other phytoghagous species that natural enemies die because of lack of food. Thus, spray programs of various types and degrees of

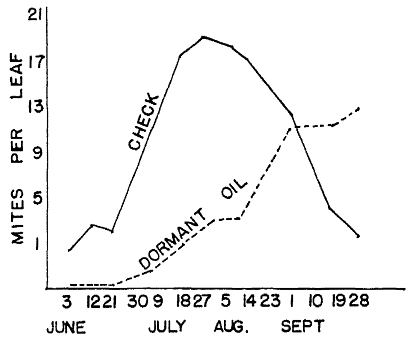


Fig. 4.—Seasonal mite populations on untreated trees as compared with trees receiving a dormant oil spray.

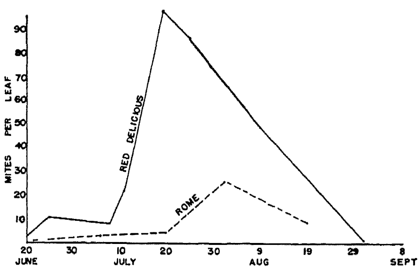


Fig. 5.—Seasonal mite populations on two different varieties of apples, both of which had received the same spray schedule.

effectiveness against our friends or our enemies have a tremendous effect on the seasonal development of mite populations.

Seasonal Infestations: When the factors of initial population, weather, natural enemies, and spray programs are considered, it is obvious that any single factor alone, or in combination with one or more of the others, can greatly change the seasonal pattern of infestation and injury. In the prior discussion on weather conditions, an example was cited showing the temperature effects on mite populations in two different seasons, (1961-1962). This situation is depicted graphically in Figure 2. It will be noted that the curves illustrating growth of mite populations on trees not treated with miticides, follow the same pattern but that the principal difference is that of time caused by different temperatures in the two years. Figure 4 illustrates the growth and decline of red mite population in a more or less normal season on trees not treated with miticides, and the difference in development when the initial population is almost eliminated by the application of an effective oil spray in early season. The course of an infestation, as influenced by the use of an effective miticide in midsummer, is shown in Figure 6.

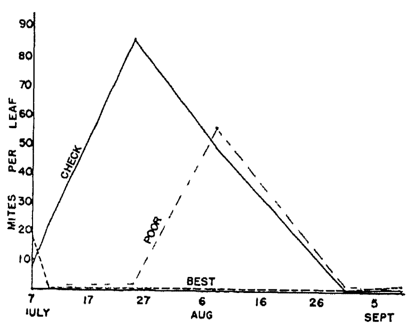


Fig. 6.—Seasonal populations of European red mite on (1) treated check trees, (2) trees treated with an inferior (poor) miticide, and (3) trees treated with an excellent miticide (best). (Spray applications—July 8 and July 18).

In this example, the contrast between the controlled population and that on the untreated check trees is very marked. In Figure 5, a comparison is made between populations of mites as they develop during the same season on a susceptible variety (Red Delicious) and a less susceptible one (Rome). Both varieties started with almost the same initial population.

In most seasons, frosts and cold weather reduce the initial population so that in late May and early June the numbers of mites are not great. However, as the season advances the ability of the mites to multiply causes a rapid increase in the population which usually reaches a peak in late July and is then followed by a decline in numbers. Where the normal spray schedule is used without including a miticidal material, the increase in numbers will continue as long as good food is available. The peak in numbers therefore, closely coincides with maximum damage to the foliage. The seasonal course of development and decline of a population on untreated trees in a sprayed orchard has been shown in Figures 4 and 6. On trees that are unsprayed, mites will seldom occur in numbers greater than one per leaf at any time during the season.

Foliage that is attacked by a few mites (5 to 10 per leaf), even though the attack continues for several weeks, may not show particular damage. If the population is then destroyed, such foliage is less suitable for feeding and the re-establishment of mites will be at a slower rate than on foliage previously unattacked. Also, the population will never be as high and seems to be more susceptible to control measures. Previous infestation is, therefore, a factor influencing the development of a later population.

In general, the most virulent and difficult populations to control are those that start with low numbers on good foliage of a susceptible variety during the early part of June. If no immediate control measures are used, such a population, aided by favorable temperatures, will reach tremendous numbers by mid-July and serious damage will follow. Such a population, if not controlled in June, will be extremely difficult to handle in July. This is due to the extremely high numbers of mites and eggs that are present throughout the tree.

Mite Dispersal: The transport of the European red mite over long distances is undoubtedly brought about by the presence of the overwintering eggs on nursery stock. These eggs are present during the period of the year in which most nursery stock is shipped; they are small, inconspicuous and easily escape the examinations of inspectors unless the eggs are so abundant as to form masses. Eggs have also been found on scion wood prepared for shipment. Millions of eggs are transported long distances every year in the calyces of the fruits, although these are rarely a hazard as far as the start of new infestations are concerned. Local distribution of the species may occur in the same manner as that of long distance spread but within the same orchard or adjacent plantings, other means are more important. Here, wind is the principal agent, which, coupled with the ballooning habit of young mites, accounts for most of the rapid spread from heavily infested orchards to those of light infestations. Ballooning occurs when the young mite spins a silk thread, one end of which is attached to a leaf or twig. The mite supports itself on this thread and will drop from two to five inches to remain suspended waiting for a wind to break the thread. When the thread is broken, the wind blows it and the attached mite to the new location where the thread becomes entangled ending the flight. Ballooning usually originates when mite injury has reduced the food supply to the point where it is not sufficient for the population. The phenomenon of ballooning *en masse* has been seen by the writer on several occasions. It is best observed in the early morning when dew has condensed on the threads spun by the young mites, thus rendering them easily visible. On one occasion, the webs were no numerous that the trees had a misty, or silvery appearance. Several hours later, following the arrival of a strong breeze, only a few threads could be found. If the balloon flight ends on another apple tree where food conditions are satisfactory, the mite will survive; otherwise, it perishes. Mites may also be carried from tree to tree on the clothing of men working in the orchard or any movable object such as a tractor. Animals brushing against infested foliage or birds alighting on twigs where mites are crawling could be agents for dispersal.

Dispersal by winds also has a bearing on control procedures and will be discussed later.

MITICIDES USED IN OHIO

In order to give a basis for the section on control, a list of miticidal materials, together with comments on their use and characteristics, is presented. This list is limited to those materials that have had commercial or wide experimental use in Ohio. They are listed in chronological order. This information does not constitute an official recommendation for European red mite control. For current recommendations, consult your County Agent or Extension Specialist.

Petroleum Oils: Kerosene emulsion was among the first insecticides that were developed from petroleum oils. Unemulsified and unrefined oils were used against scale insects in the later 1890's, to some extent as late as 1904. These oils were unsafe and numerous trees, especially peach, were killed or injured by them. Certain proprietary, emulsifiable oils were developed soon after this and were used rather extensively up to 1923. Scalecide was one of the better known brands of this type and was used by Houser (18) in his first experimental work against the European red mite in Ohio in 1921. Based on results of this experiment, it was recommended in 1922. Incidentally, this brand is still on the market.

Other oils, particularly the types that were used to lubricate stationary engines, were soon found to be effective and were recommended. These oils were either made into a stock emulsion prior to use or were emulsified in the spray tank immediately before spraying. Such oils came into general use about 1924. The more highly refined oils, in which the unsaturated hydrocarbons are reduced in amount, were first marketed about 1926. "Volck" summer oil was one of the first of the highly refined types that could be safely used on trees in foilage. Usually the concentration recommended was no more than one percent.

Less highly refined oils may be safely used in the dormant period but these have been supplanted in recent years by the superior emulsifiable oils that can be used safely even into the "pink" period. If combined with fungicides, the danger of phytotoxicity increases and instructions concerning such combinations must be carefully followed. Under no conditions should oils be combined with sulfur or Captan, nor should these latter materials be used soon after an oil spray. Oils have been extensively used in orchards for a period of over 50 years, but despite this fact, mites have not developed resistance to them. These materials, therefore, are of great value to growers.

Botanicals: Rotenone, which is derived from plants such as *Derris* and *Lonchocarpus* has some miticidal action and had a limited use against the European red mite prior to World War II. Its action is too short-lived and costly to be economical. Other botanicals, such as pyrethrum and nicotine, are not miticides.

Dinitros (Dinitrophenols): Several different compounds belong to this group. Of these materials, dinitrobutylphenol (DN 289) and related forms are highly phytotic and are used only as dormant sprays where they are effective against mite and aphid eggs. Dinitrocyclohexylphenol (DN Dry mix No. 1) and dinitrocresol (Elgetol 300) are less phytotoxic but are restricted to dormant sprays, except for thinning fruits or in low dilutions against mites. However, even at weak concentrations, injury to foliage may occur under certain conditions. DN-111 is effective against mites but is only relatively safe for summer use. The dinitros were developed just prior to World War II and were widely used up to about 1947, when they were replaced by less phytotoxic materials. They may still be used as dormat sprays. The phytotoxic properties of the group are indicated by the fact that many related compounds are used as herbicides.

Chlorinated Hydrocarbons: Dimite (di-(p-chlorophenyl)-methylcarbinol) was developed by the Sherwin-Williams Company around 1950. It is a fairly effective, but at times eratic, miticide and has had only limited use in Ohio.

Chlorobenzilate (1955) is an effective miticide which is recommended but which has had only limited use in Ohio. No reports or resistance have been received to January 1963. Some reports of injury to fruits have been received from the far west but this has not been observed in Ohio.

Kelthane (1956) is a highly effective miticide which has appeared in several formulations. There are reports from numerous orchardists of resistance to Kelthane which has lessened its usefulness in the seasons of 1961-62. In orchards where it has had only limited use, it may still be employed with confidence.

Organo-phosphates: There is a long list of these materials, the most common of which will be treated separately. All are toxic to humans but there is a wide range from minimum to maximum toxicity. Practically all have been developed in the last 20 years but have been used in the field only from 1948 to the present.

TEPP was the first organo-phosphate to be used in Ohio where it was widely employed against the periodical cicada in 1948. It is effective against motile mites but has no residual effect. It is recommended in combination with tetradifon (Tedion) where a quick knock-down is desired. Some mite populations may be resistant to TEPP.

Parathion was used experimentally as early as 1947 and came into general use in 1949. Resistance was first suspected in 1952 and was confirmed in 1953. Since this date mite populations in all parts of the state have been shown to be resistant to parathion. Although this material is no longer recommended as a miticide, it is still effective against a number of other orchard pests.

EPN an effective miticide, was first tested in 1949. A few growers used limited amounts in 1950, and it was generally recommended in 1951. Resistance to it became general in 1956 and its recommendations was discontinued.

Malathion was introduced in 1952 but almost all populations of mites that were resistant to parathion were soon resistant to it. It is a relatively safe phosphate and is widely used in general control of insects. However, it is not recommended for use in commercial orchards against mites.

Demeton (Systox) was introduced in 1952 and was very efficient against mites for several years in some orchards but in others resistance appeared after a few treatments. It is a very effective aphicide but its use against the European red mite is limited.

Diazinon also made its appearance in 1952. It is more of a general insecticide but in seasonal tests when used in several consecutive sprays has given good commercial control of mites.

Guthion, and the next three chemicals, appeared in 1956. Of these, Guthion has far greater usage due to its effectiveness against practically all orchard pests. However, in 1961 numerous orchards reported resistance by mites and this trend continued in 1962. It is still effective against other pests.

Carbophenothion (Trithion) is a very effective miticide but has not had as wide usage as Guthion.

Phorate (Thimet) is a systemic but in Ohio its application to the soil under apple trees has not resulted in mite control. As a foliar spray it is fairly effective.

Delnav, ethion and phosphamidon appeared in 1957-58. When used at dosages somewhat higher than recommended on the label, they are generally effective. As yet, none of them has had extensive use in Ohio.

Dimethoate has been used in experimental work since 1959 but is not approved for use in 1963. It is an efficient miticide and aphicide.

Numerous other organo-phosphate compounds have been used experimentally and some have had limited commercial usage. However, for various reasons none of these have gained recommendation.

Sulfur-based Compounds: A number of these compounds have been formulated and tested but only the following have been recommended and used in Ohio.

Aramite was introduced in 1953 and was effectively used until 1953 when it was denied registration by the Food and Drug Administration due to its possible carcinogenic nature. Aramite is of interest in that resistance to it by mites seems to develop slowly.

Ovex (Ovotan) was also introduced in 1953 and was successfully used for about three years before resistance to it was first reported. In some areas it is still in use; but generally it is no longer recommended.

Genite 923 (1955) is recommended and successfully used as an additive to the "pink" spray. Later in the season it is not so effective and there have been some reports of injury when used in midsummer.

Chlorbenside (Mitox) (1955) is recommended as an additive to the "pink" spray where it has been successfully used. In orchards where mites are resistant to ovex, it may not be as effective as elsewhere. If used in summer, it may cause injury to fruits.

Tetradifon (Tedion) (1959) is a slow acting miticide with excellent residual effect. TEPP should be combined with it for maximum results. Resistance has been reported in Ohio.

Carbonates: Several effective materials are being developed and give promise of future usefulness. One such compound, called Eradex, is being used on ornamentals but is not adaptable for fruit.

Polybutenes: These are series of butylene polymers, being predominately high molecular weight mono-olefins (85-95 percent), the balance being isoparaffins, which are very sticky and kill by entangling the living mites. They are in process of development and may be highly useful as mites should not become resistant to them. Their use will probably be limited to early season sprays as summer applications have injured foliage.

After having read the foregoing section, one can not fail to be impressed with the fact that every miticide that has been widely used, except the oils, has become or is becoming ineffective due to resistance. This is most unfortunate and will be fully considered in the discussion of control measures.

THE CONTROL PROBLEM

Basic Principles of Control: It has already been stated that the natural enemies of mites will control the injurious species on unsprayed fruit trees. However, even the application of a few sprays changes this condition and the phytophagous species become troublesome, particularly the European red mite.

Sprays affect the natural enemies of phytophagous mites in two ways. First, sprays having miticidal properties such as oil may so reduce the mite population that the natural enemies have little or no food and are forced to leave the tree or die. In any event, the few injurious mites that have escaped the spray are free to multiply unchecked. Second, the spray materials that are being used may be highly toxic (*i.e.* DDT) to the natural enemies of the injurious mites. This also releases the harmful species and permits their breeding at unhindered capacity.

Much time and attention has been given to the problem of promoting the welfare of beneficial insects and mites, but as yet (1963) little progress has been made. The two adverse effects of the use of sprays as stated in the last paragraph still renders the economic use of biological control impossible under most conditions. Therefore, in a realistic approach to the problem of mite control, biological control by natural enemies cannot be considered. Of course, no one knows what the future will bring and it is possible that some great discovery may make it "the control" in years to come.

It is also possible that spray materials that are effective against harmful insects and non-injurious to beneficial forms, may be developed. However, when the number of injurious insects are considered, the immediate development of such a spray chemical is very doubtful. Therefore, at present the problems of mite control are those of chemical usage: What chemical, at what dilutions, and how applied?

Chemicals that have miticidal properties have already been listed and due to constant changes in recommendations will not be further discussed. Some advice however, may be given regarding dosage. At one time it was thought that minimum dosages, just sufficient to hold the mites in check, might be used, especially if frequent applications were to be made. However, experience has shown that minimum usage tends to speed up the development of resistance and that far better results can be secured when maximum amounts of the miticide are applied. With the application of each spray, the highest possible mortality must be secured and the use of adequate amounts of the spray chemical is one way of achieving this end.

The timing of the spray application is very important. In the spring as the overwintering egg approaches hatching, and the rate of its development increases, it becomes more susceptible to the oils and other spray materials. This means that the nearer to hatching that the spray can be applied, the more effective it will be. In fact, oil is most effectively used when it is applied after hatching has started, since young mites are also quite susceptible to it. The period in the seasonal growth of the tree that most nearly corresponds to the effective time for use of oil is the "pink". At this time, a superior oil at 1 percent will give fully as good results as 2 percent oil applied in the dormat or early delayed dormant period.

If oil or another effective material is used in early season, (*i.e.* the "pink") mites should be held in check from six weeks to three months, depending on the season and the thoroughness of application. However, the grower should inspect the orchard frequently and when mites average from 2 to 5 per leaf, the first full strength summer miticidal spray should be used against them. This spray should be followed by a second application in 8 to 10 days, depending on temperatures that are prevailing. The second application is necessary to kill mites that have hatched since the first spray and before they become adult and deposit more eggs. The two consecutive summer sprays, spaced relatively close to each other, are very important. Complete control for the balance of the season should follow their use.

In summary, the three periods for effective timing are (1) just before or shortly after the overwintering eggs start hatching; (2) when summer mites average no more than 2 to 5 per leaf· and (3) from 8 to 10 days following the first miticidal summer spray.

Since populations of the European red mite distribute themselves equally over the entire tree, it is necessary that complete and thorough coverage with any spray be secured. A good sprayer is, of course, a decided asset in securing good coverage but acceptable work can be done even with a poor spray rig if care is exercised. Since the overwintering eggs are located for the most part on the undersides of the branches, spray must be directed so as to cover these areas. With airblast sprayers this is rather difficult to do, especially when the orchard is located on a hillside. Under such conditions the application of the spray from hand guns, operated by men on the ground, may be more efficient. In many instances, however, readjustment of nozzles to secure coverage of the undersides of the branches may be made. This applies to all types of booms on sprayers and airblast machines.

During the summer months, the great majority of the mites live on the undersides of the leaves. Hence, it is necessary that the spray cover this side of the foliage. Sufficient quantities to cover adequately all surfaces on the tree must be used. This will require at the minimum, one-half gallon of spray for each year of the tree's age and in most cases, three-fourths of a gallon is better. Airblast sprayers are generally quite effective in distributing the spray throughout the tree and in turning the leaves so that all surfaces are covered. Nozzle adjustment for trees of different sizes is necessary for best results.

It has already been stated that mites are blown from one tree to another by wind. In order to prevent such migration, it is best to start spraying on the windward side of the orchard. In Ohio, spraying should usually start on the west side of the planting since the prevailing winds are from that direction. This will prevent the movement of mites from untreated trees to those that have been recently sprayed.

Resistance: In current biological literature, the word "resistance" is used for want of a better term. As used, it means that insects, mites or other organisms are able to live and multiply in the presence of a chemical that in past years caused a high rate of mortality to their ancestors. The development of resistance to certain spray materials by certain pests has been known to entomologists for almost fifty years. Reports, starting with that of Melander (22) have appeared with increasing frequency, especially in the last 15 years, during which time the problem has assumed serious proportions. Resistance has been found among all the important orders of insects and many phytophagous mites and new cases are developing annually. Practically all of our better known and more efficient insecticides and miticides have been rendered less useful by resistance among different insect and mite pests. It is now considered as one of our most serious problems in the field of mite control.

Resistance is developed by the selective action of the chemical in use. Among almost any population of mites or insects, there are certain individuals that are "stronger", or in other words, posses a certain trait or an inherent capacity that enables them to resist or escape the action of the chemical. This may occur when a high dosage or when a low dosage is applied. The individuals that escape or resist the effects of the chemical treatment transmit the enabling factors to their progeny. These, when subjected to the same chemical, will escape in even greater numbers as the "stronger" individuals again exhibit resistance. Thus, as the treatment is repeated time after time and the "stronger" individuals escape, we finally have a mite or insect population which is composed almost entirely of individuals that are resistant and cannot be killed in any great numbers by the particular chemical.

Resistance to various spray materials on the part of the two-spotted spider mite, *Tetranychus telarius* (L.) was noted as early as 1937. Resistance by the European red mite was not reported until O'Neill and Hantsbarger (25) of Washington published on the failure of parathion to control in 1951. Since that time, numerous publications originating from all apple growing areas have dealt with the problem of resistance on the part of the European red mite. Some possible means of correcting or alleviating resistance will be discussed in the next section.

Combating Resistance: In ordinary orchard practice, it is customary to use one miticide continuously to and beyond the point where control is secured. Then another miticide is selected and used to the same extent. This general pattern of usage is unsatisfactory in that toward the end of its period of usefulness, several applications of the miticide are applied usually without benefit. The grower knows that control is imperfect but thinking that weather was not right, or dosage was not correct, or blaming other factors, continues to use the same material. This situation has cost him time, money, worry, and crop damage, before he finally changes to another miticide. This practice also presupposes that another effective miticide will always be available for use; a supposition that is doubtful in view of the rate at which the European red mite has developed resistance to many miticides. In fact, there are now (1963) a few Ohio orchards where the owners have reason to feel that their particular mite populations are resistant to all available miticides except oils. Despite the foregoing objection, some individuals feel that the customary pattern of continuous usage as described, is enough to handle the resistance problem.

Others think that the problem may be solved by developing specific spray chemicals that will not harm the natural enemies of the mites and that a type of integrated control would thus be secured. This has already been considered and found impractical for the present.

A more practical approach is to use the best possible practices for each spray application and thus secure maximum kill. Many of the better growers who obtain excellent results with each spray seem to have less trouble with resistance.

In the discussion and listing of the different miticides, it was pointed out that they belong to several distinct chemical groups, and that these groups kill by different physiological action. Some may inhibit the production of certain necessary enzymes, others act as nerve poisons, while others coagulate proteins. Since these different groups are available, it would seem logical to use them in a rotational pattern without waiting for a mite population to develop the extreme resistance produced by continuous use of one type. This would enable the grower to avoid loss of money and labor and resulting damage that so frequently occurs when one material is used year after year. The history of numerous orchards, where a single miticide has been used continuously, bears witness to the impractical results of such usage.

On the other hand, it has been noted that growers who made frequent changes in the spray chemicals, that they were using, obtained better control, especially where the European red mite was concerned. For example, one grower who has always used early season oil or dormant dintro and alternated between organo-phosphates and sulfur-based miticides for summer use has not had a serious mite problem for over 12 years. Observations and experiments in the orchards of the

Ohio Agricultural Experiment Station also confirm the value of rotational use of spray chemicals. These data have been published (11) and will not be repeated here.

Due to the large number of miticides that are available, many different spray schedules of a rotational nature may be planned. For example, one might include oil, or chlorbenside (Mitox) or Genite 923 in early season and then use an organo-phosphate in midsummer. The next year a different one of the first three could be used and in midsummer a chlorinated hydrobarbon could be employed. In the third season, a sulfur-based material in midsummer could follow the third remedy for early use. Actually, a somewhat simpler schedule is probably to be preferred. Since no resistance has developed to the use of the oils, this program would start each year with an application of oil and then in midsummer a material from one of the three major groups, namely, the organo-phosphates, the chlorinated hydrocarbons, and the sulfur-based, could be used in rotation. Such a schedule has been used in one of the experimental orchards at Wooster for the last six years and excellent control of mites has been secured.

SUMMARY

An attempt has been made to present the more important facts regarding the biology and control of the European red mite. In unsprayed orchards, the low numbers of mites are due to natural control which cannot operate under the conditions imposed by the use of a modern spray program for insects and diseases. Therefore, sprayed orchards are subject to serious infestations. Numbers of mites either great or small at any seasonal period depend on (1) initial population, (2) weather conditions, (3) natural enemies, (4) varieties, and (5) the spray program in use. Resistance is a very serious factor in control and in order to combat it most effectively, a program of rotational spraying is advised.

LITERATURE CITED

1. Austin, M. D. and A. M. Massee. 1947. Investigations on the control of the fruit tree red spider mite (**M. ulmi** Koch) during the dormat season. Jour. Pom. and Hort. Sci. 28(3-4):227-253.

2. Cagle, L. R. 1946. Life history of the European red mite. Tech. Bull. 98, Virginia Agric. Exp. Sta.

3. Clancy, D. W. and N. H. Pollard. 1952. The effect of DDT on mite and predator populations in apple orchards. Jour. Econ. Ent. 45:108-114.

4. Collyer, E. 1956. Notes on the biology of some predaceous mites on fruit trees in southeastern England. Bull. Ent. Res. 47:205-214.

5. Collyer, E. 1952. Biology of some predatory insects and mites associated with the fruit tree red spider mite. Jour. Hort. Sci. 27(2): 117-129.

6. Collyer, E. 1952. Biology of some predatory insects and mites associated with the fruit tree red spider mite. Ph. D. Thesis, University of London.

7. Cutright, C. R. 1944. Populations of the European red mite as affected by spray schedules. Jour. Econ. Ent. 37(4):499-502.

8. Cutright, C. R. 1947. Effectiveness of acaricides in DDT sprayed apple orchards. Jour. Econ. Ent. 40(4):557-561.

9. Cutright, C. R. 1956. A three-year field study of a mite population resistant to parathion. Res. Cir. 37, Ohio Agric. Exp. Sta.

10. Cutright, C. R. 1958. Fundamentals of mite control on apple. Proc. Ohio State Hort. Soc., 65-74.

11. Cutright, C. R. 1959. Rotational use of spray chemicals in insect and mite control. Jour. Econ. Ent. 52:432-434.

12. Ehara, 1956. Tetranychoid mites of the mulberry in Japan. J. Fac. Sci., Hokkaido University, Ser. VI Zool. 12:499-500.

13. Ewing, H. E. 1912. The occurrence of the citrus red spider, **Tetranychus mytilaspidis** Riley, on stone and pomaceous fruit trees in Oregon. Jour. Econ. Ent. 5:414-415.

14. Garman, P. and J. F. Townsend. 1938. The European red mite and its control. Conn. Agric. Exp. Sta. Bull. 418.

15. Garman, P. 1948. Mite species from apple trees in Connecticut. Conn. Agric. Exp. Sta. Bull. 520.

16. Groves, J. R. 1951. A synopsis of world literature on the fruit tree red spider mite. Commonwealth Inst. of Ent. 180 pp.

17. Hintz, H. W. 1953. Laboratory tests of acaricides on eggs of the European red mite. Jour. Ent. 46:112-115.

18. Houser, J. S. 1923. The European red mite in Ohio. Proc. Ohio State Hort. Soc. 56-59.

19. Lord, F. T. 1949. Influence of spray programs on the fauna of apple orchards, in Nova Scotia. III. Mites and their predators. Canadian Ent. 81:202-214, 217-230.

20. Lord, F. T. 1956. Influence of spray programs on the fauna of apple orchards in Nova Scotia. IX. Studies on means of altering predator populations. Canadian Ent. 88:129-137.

21. MacPhee, A. W. 1953. Influence of spray programs on the fauna of apple orchards in Nova Scotia. V. Candian Ent. 85:33-40.

22. Melander, A. L. 1914. Can insects become resistant to sprays? Jour. Econ. Ent. 7:167-172.

23. Miller, A. E. 1925. An introductory study of the Acarina or mites of Ohio. Ohio Agric. Exp. Sta. Bull. 386.

24. Neiswander, C. R. and V. H. Morris. 1940. Introduction of selenium into plant tissue as a toxicant for insects and mites. Jour. Econ. Ent. 33:517-525.

25. Newcomer, E. J. and M. A. Yothers. 1929. Biology of the European red mite in the Pacific Northwest. Tech. Bull. 89, U.S. Dept. of Agric.

26. O'Neill, W. J. and W. H. Hantsbarger. 1951. Apple and pear pest control experiments for 1951. Proc. Wash. State Hort. Assoc. 47:134-137.

27. Pickelt, A. D. 1946. Influence of spray programs on the fauna of apple orchards in Nova Scotia. Sci. Agric. 26:590-600.

28. Pritchard, A. E. and E. W. Baker. 1955. A revision of the spider mite family Tetranychidae. Memoir Ser. Vol. 2 Pacific Coast Ent. Soc.

29. Pritchard, A. E. and E. W. Baker, 1952. A guide to the spider mites of deciduous fruit trees. Hilgardia 21:253-287.

30. Snetsinger, R. 1959. Population relationships of spider mites and Typhlodromid mites on apple trees in central Illinois. Trans. Illinois Acad. of Sci. 52:128-133.

31. Tsugawa, C., M. Yamada and S. Shuasaki. 1961. Forecasting the outbreak of destructive insects in apple orchards. Japan Jour. of Applied Ent. and Zool. 5:167-173.